

AN OVERVIEW OF NON-METALLIC BRUSH SEAL TECHNOLOGY

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An Overview of Non-Metallic Brush Seal Technology

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Abstract: Non-metallic brush seals are ultra-low flow sealing elements ideal for low pressure differentials (<30 psid) and low temperature (typically <300 degF) applications. The compliant bristle pack of a non-metallic brush seal is advantageous in terms of sealing capability during transients. However, if not designed properly, the bristle pack compliance can be detrimental to the performance of the seal. GE Global Research has investigated the stiffness and heat generation properties of non-metallic brush seals made from Kevlar and Carbon Fiber. The presentation will review the progress made on the design points of the seals, as well as highlight some current commercial applications of the technology.

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Why non-metallic brush seals?

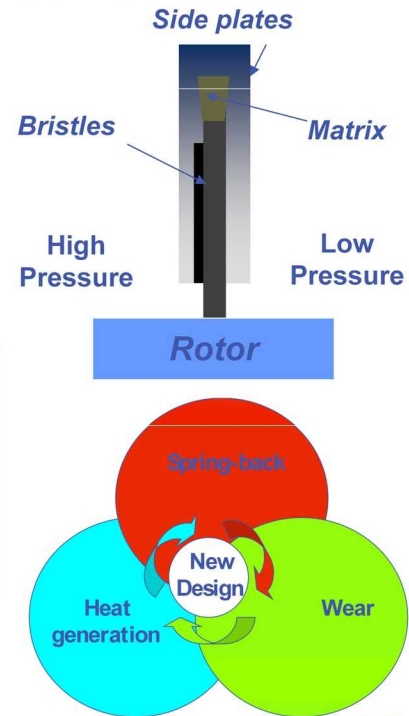
Excellent sealing ($< 0.002''$ effective clearance)

Wear particulate benign in bearing environment

Good oil preclusion properties

Compliant bristle pack

- No rotor scoring or marking
- Source of heat generation
- Wear debris caused by stiffness

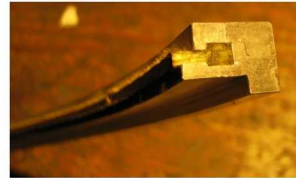
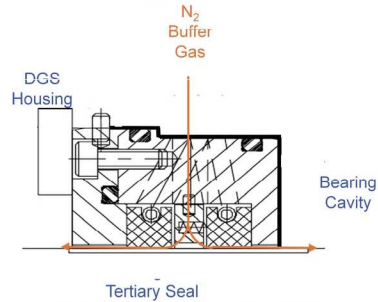
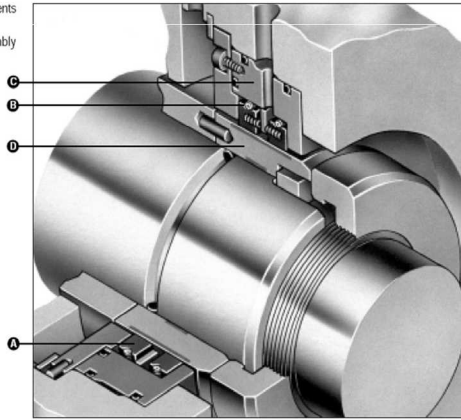


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Business driver: KFBS for LNG compressors

- A - Bushing Segments
- B - Garter Spring
- C - Housing Assembly
- D - Shaft/Sleeve



Circumferential carbon seals can be a reliability issue in the field



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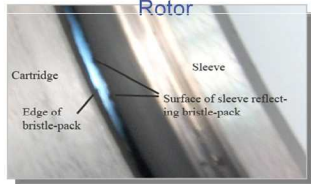
GE Oil & Gas was not the primary business driver in the initial development of non-metallic brush seals. However, GE O&G was the first to heavily invest in the technology development to ensure a robust seal design.



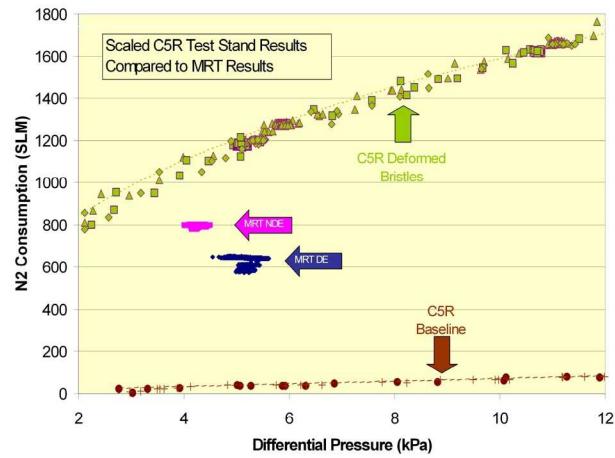
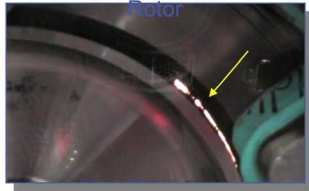
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Lesson Learned (the Hard Way)

Gap between MRT Seal & Rotor



Gap created: Lab Seal & Rotor



Assembly process not simulated & led to high leakage



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Early 2007 field trial had high leakage. RCA following the field trial failure revealed that the bristle pack was poorly designed—it was too soft from a stiffness perspective. The assembly process of getting the seals onto the rotor was never simulated in the subscale testing, thus never identified as a potential issue prior to field testing.



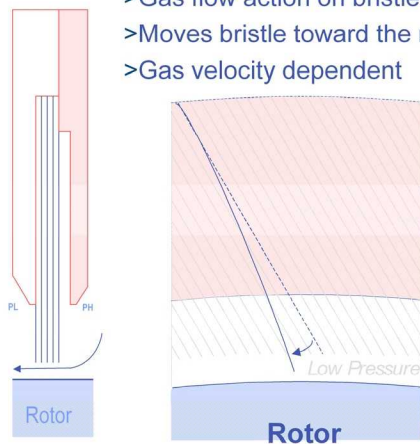
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Bristle shape recovery

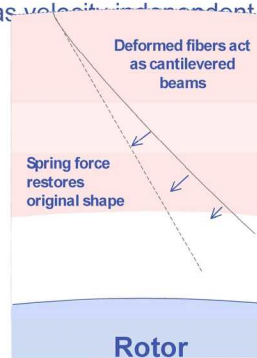
Blowdown

- >Gas flow action on bristle
- >Moves bristle toward the rotor
- >Gas velocity dependent



Spring-back

- >Internal bending stress
- >Restores bristle to neutral position
- >Gas velocity independent



Friction in pack overcome by blow-down and spring-back

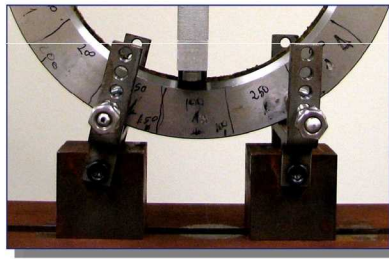


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There are two main factors that affect bristle pack recoverability: blow-down and spring-back. The focus of this research is on spring-back, as it is a property inherent to the seal design and not a function of differential pressure.

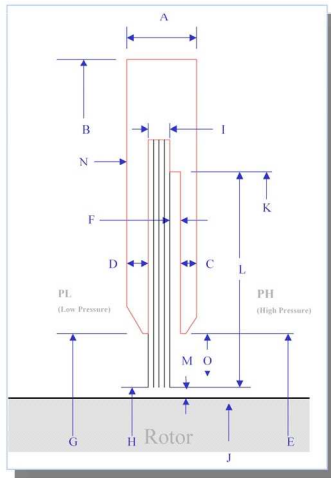
Spring-back quantification



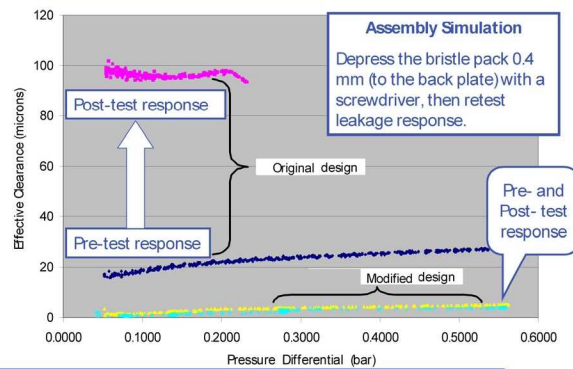
- > Insert / Retract Rate: 0.25mm/s
- > Cycles per test point:
 - 4 in initial testing
 - 10 in subsequent testing
- > Maximum compression: 0.9 mm
- > Output: Load vs. displacement curves generated

Spring-back test setup at GE GR in Niskayuna, NY.

Design changes & results



Parameter	Label	% Original
Fiber Free Length	L	31%
Bristle-Rotor Interference	M	146%



Modified bristle design improved Springback and leakage



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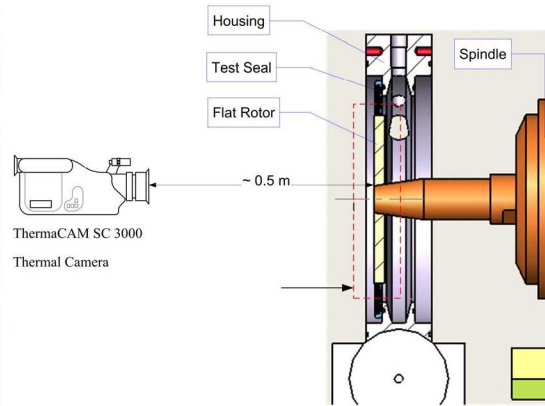
Identified design changes to improve the stiffness of the bristle pack led to a successful second attempt both in the subscale and in a field trial.



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Heat generation testing: setup



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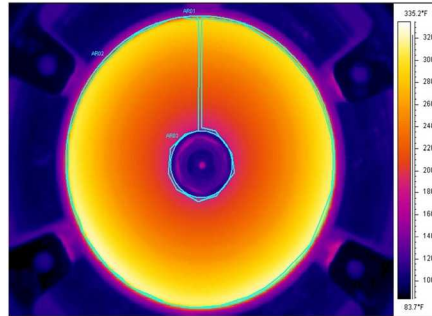
Heat generation testing setup at GE GR, Niskayuna, NY.

Heat generation test procedure

1. Set rotor speed
2. Monitor average temperature at inner 1" diameter of rotor
3. Record thermal gradient throughout rotor once steady-state conditions are met
4. Increase rotor speed

Test Conditions:

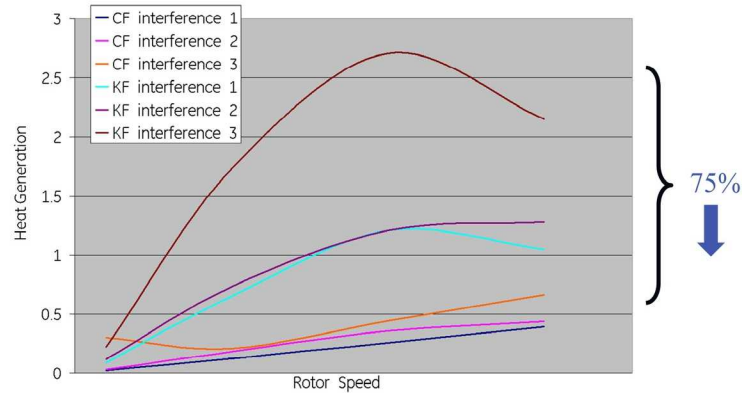
- > 7, 33, 67, and 100% rpm
- > Clearance, L-L, and Int



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Carbon fiber outperforms Kevlar fiber for reduced heat generation



75% reduction in heat generation compared to Kevlar fibers



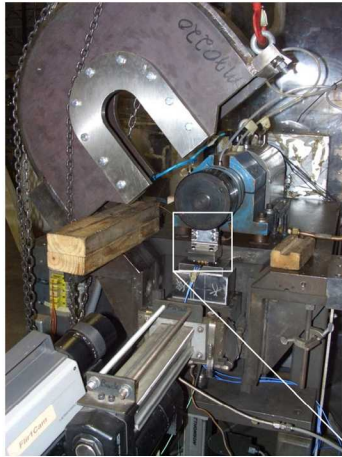
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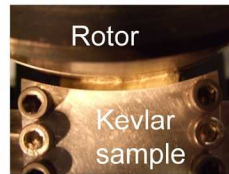
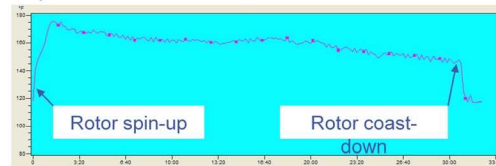
Seal designs were similar for both carbon and kevlar fiber.

Wear testing results

At maximum running speed, bristle pack interference will wear completely within 30 minutes.



IR camera captures initial thermal spike and roll-off as fibers wear



→ Second phase of testing to investigate slow-roll running conditions.






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Wear testing setup at GE GR in Niskayuna, NY.

Carbon Fiber versus Kevlar Fiber

Property	Kevlar	Carbon
Fiber diameter	Yellow	Green
Heat generation	Red	Green
Sealing pressure	Yellow	Yellow
Sealing temperature	Yellow	Green
Seal manufacturability	Green	Red
Final bore cut	Yellow	Green
Bristle pack robustness	Green	Yellow
Field experience	Green	Red

 = best
 = neutral
 = poor



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This table compares the identified property in the leftmost column between both the kevlar and carbon seal designs. Since it is comparing just these two seals, each row compares the stated property, where one seal is usually identified as being better or worse than the other.

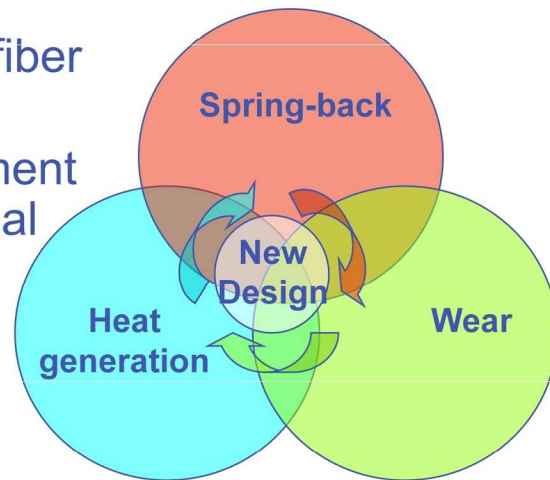
Summary

Choice of Carbon or Kevlar fiber is application specific

Kevlar seal design development more mature than carbon seal equivalent

Carbon fiber has better heat generation characteristics

Kevlar fiber has field-demonstrated robustness to rotor transients



Next steps: Focus on application deployment for Kevlar seals
& continued development of carbon fiber seals



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References

- Ruggiero, Eric J., Mehmet Demiroglu, Jason Allen, and Mark Lusted. "Heat Generation Characteristics of a Kevlar Fiber Brush Seal," *AIAA Joint Propulsion Conference*, July 8 – 11, 2007, Cincinnati, OH.
- Ruggiero, Eric J., Jason Allen, and Mark Lusted. "Heat Generation Characteristics of a Carbon Fiber Brush Seal," *AIAA Joint Propulsion Conference*, July 21-23, 2008, Cincinnati, OH.
- Ruggiero, Eric J., Paolo Susini, and Mark Lusted. "Kevlar Fiber Brush Seals for LNG Compressors," *AIAA Joint Propulsion Conference*, July 21-23, 2008, Cincinnati, OH



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